Very Shallow Water/Surf Zone Mine Countermeasure (VSW/SZ MCM) Reconnaissance Concept Assessment and Development

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LONG-TERM GOALS

This project will develop a simulation-based assessment process that will provide an objective, systematic, and cost-effective method to evaluate the performance of advanced VSW/SZ MCM concepts. This process will be used to help guide system development efforts from the initial requirements definition, to the notional concept assessment, and through the detailed, physics-based system analysis.

OBJECTIVES

The FY 00 objectives were to:

1. Continue development of the required operational background information to provide consistent guidance and definition for all analysis/assessment efforts.
2. Complete the high-level, probabilistic-based version of the Autonomous Littoral Warfare Systems Evaluator (ALWSE-MC).
3. Design the physics-based version of the Autonomous Littoral Warfare Systems Evaluator (ALWSE-ES).
4. Continue studies to define fundamental system performance parameters.

APPROACH

Component technologies, which are applicable to the very shallow water/surf zone (VSW/SZ) mine countermeasures (MCM) reconnaissance mission, are assessed by a combination of methods that may span the spectrum of high-level "back-of-the-envelope" evaluations to field tests of prototype hardware. Components that are then perceived to be potential solutions are "integrated" into notional system concepts. These concepts are then subjected to an iterative evaluation process that quantifies the potential operational and system performance effectiveness. The Autonomous Littoral Warfare Systems Evaluator (ALWSE-MC) is the primary tool for these evaluations.

After a system(s) has been defined with some degree of confidence, components of the system are modeled and integrated into a physics-based version of ALWSE (ALWSE-ES) simulation for a higher fidelity assessment. This level of assessment will provide high confidence predictions of in-field performance and will ultimately be used to produce a definition of the best candidate system for follow-on development in the acquisition cycle.

The key individuals participating in this work are the following:

- R. Dale Rhinehart, Coastal Systems Station, Project Management
- N. Rodriguez-Casanova, Coastal Systems Station, Concept Assessment
- M. Eadie, Coastal Systems Station, Simulation
- S. Gastar, Logicon-Syscon, Concept Assessment
- L. Howell, BaE Systems, Concept Assessment
- W. Littlejohn, Coastal Systems Station, Modeling

WORK COMPLETED

1. Briefed various fleet commands and updated the Concept of Operations (CONOPS) with current fleet perspectives.
2. Developed a draft Mission Functional Decomposition for the VSW/SZ MCM reconnaissance mission.
3. Completed the draft VSW Detachment Baseline Mission Profile and briefed appropriate fleet units.
4. Completed the integrated Operational Scenario.
5. Developed a draft Concept of Employment for a system utilizing current technology Unmanned Undersea Vehicles (UUV's) and bottom-crawling vehicles.
6. Completed studies to quantify the performance of SZ crawling vehicles:
    a. The potential impact of countermeasures on mission performance.
    b. The impact of external navigation updates on mission performance.
    c. Define an optimum length of time between course changes while using a random search tactic.
    d. Define an optimum angle change while using a random search tactic.
    e. Determine if search area geometry impacts area search times.
    f. Determine if starting position impacts area search times.
    g. Optimize test matrix parameters for the FY00 SZ field test/demo.
7. Completed studies to quantify the performance of VSW UUV's:
    a. Test planning support for Fleet Battlelab Experiment (Hotel) demonstrations.
    b. System performance analysis in support of the UUV Analysis of Alternatives.

8. Completed the baseline version of ALWSE-MC and added multiple improvements to accommodate the various studies.
9. Completed the ALWSE-MC users guide and tutorial.
10. Completed implementation of the Real-time ALWSE Visualization Environment (RAVE) for ALWSE-MC.
11. Completed the design of the ALWSE-ES architecture.
12. Successfully demonstrated the end-to-end software development process by using object information models, component state models, and the CASE tool to generate the executable code for a very preliminary version of ALWSE-ES.
13. Developed an initial motion model for bottom-crawling vehicles and integrated it into the ALWSE-ES simulation.
14. Completed modifications to convert the Shallow Water Acoustic Toolset (SWAT) model to a *.dll format.
15. Completed a model to predict forces (at depth) on vehicles due to wave effects in the VSW and SZ regions.
16. Completed interfacing initial terrain data into the ALWSE-ES simulation.

RESULTS

The Concept Assessment and Development effort consists of a concept assessment task and a modeling and simulation task. The purpose of the Concept Assessment task is to evaluate system performance bounded by operational and engineering constraints. The purpose of the modeling and simulation task is to develop the tools required to facilitate the assessment process. The following is a summary of the results of these efforts.

The ALWSE-MC simulation was completed in FY00 and is a significant new tool for the development of VSW/SZ systems. ALWSE has two distinct forms – ALWSE-MC and ALWSE-ES. ALWSE-MC is a probabilistic-based analysis tool used to study the behavior and characteristics of autonomous underwater vehicles performing mine reconnaissance, mapping, clearance, and surveillance in a littoral region. Parametric characteristics of the vehicle and environment under test are input through a graphical user interface. These inputs include parameters such as number of vehicles to deploy, search pattern characteristics, sensor characteristics, vehicle speed and behavior patterns, vehicle endurance, reliability, navigational accuracies, and vehicle deployment schemes. Separate databases and editors are used to define the type and configuration of mines, obstacles, and countermeasures. Either "A-B" or "P(y)" data may characterize sensor-target interactions. Different scenarios can be created and managed via the simulation's file management tools.

ALWSE-MC was designed to be used by analysts without a steep learning curve. During program execution, the analyst can view the data from either of two different modes. The user can select status indicators, lane boundaries, and vehicle tracks or he can view the data using the Real-time ALWSE Visualization Environment (RAVE). RAVE is a real-time, 3D data visualization concept that allows the analyst to view the progress of the simulation from an unlimited number of perspectives. It allows for intuitive interpretation of the simulation data. The simulation data can also be automatically postprocessed using commercial MatLab program interfaces. ALWSE-MC runs on any “vanilla” PC and will run under all of today's standard desktop operating systems (Windows 95, 98, NT, and 2000).

ALWSE-ES is a follow-on development effort to ALWSE-MC. ALWSE-ES will also be used to study the behavior of autonomous vehicles but will employ high-resolution, physics-based models to characterize system performance and environmental impact in lieu of the parametric approximations of MC. Modeling components include three and six degree of freedom vehicle motion models, environmentally induced forces (e.g., sea surface, current), acoustic propagation effects, and detailed sensor processing models. This tool will allow the analyst or engineer detailed insight and examination of the environmental impact on system performance.

The ES simulation currently employs a development method based on the Object-Oriented Analysis software development paradigm. The simulation infrastructure will be designed to allow maximum flexibility in terms of model interfacing, timing control, range links, and hardware-in-the-loop capabilities. The Computer-Aided Software Engineering tool, BridgePoint (by Project Technologies), is used to automate the software engineering process. Using a modified MC-2012 model compiler, we have automated the software development process from design through automatic code generation.

In order to guide system development efforts, it is necessary to provide a “top-down” definition of the specific mission(s) that each system or component of the system must perform. This definition must be provided within the context of the operational environments and constraints within which these systems or components must operate. During FY99, much of the very top-level definitions were drafted and subsequently briefed to fleet units to solicit their inputs. FY00 work consisted of modifying the drafts to include the fleet inputs and then refining those high-level inputs to provide a higher resolution detail of the requirements. The results are contained in a document entitled “The VSW/SZ MCM Reconnaissance Concept of Operations.” The document defines the high-level need for VSW/SZ reconnaissance within the context of an amphibious assault, establishes the background for that need, and integrates this mission with other warfare disciplines that are operating within the same theater.

High-level operational requirements must be interpreted to provide a lower-level definition of an operational mission. During FY00, the draft “VSW/SZ MCM Reconnaissance Mission Definition” document was established to provide that interpretation. This document deconflicts the high-level requirements set forth in the Concept of Operations and establishes specific mission requirements to satisfy the operational requirements. It defines the specific mine and obstacle threat, the physical operational environment under which the system(s) must operate, decomposes the mission into specific functional components, and develops mission profiles to define required timelines for mission execution.

The VSW/SZ MCM Reconnaissance system studies define important parameters and their expected impact on the performance of candidate systems that may meet the requirements set forth in the CONOPS and Mission definition documents. FY00 work in this area consisted of multiple studies to quantify these parameters. The results of these studies have been used as inputs for various efforts within the VSW/SZ MCM community. Summaries of the FY00 studies are described below.

Observations pertaining to swimming UUV's performing the VSW/SZ MCM reconnaissance mission:

1. Sonar sensors, by themselves, contribute more to overall performance than any other single type of sensor.
2. Significant improvement in the probability of target classification and the reduction of false alarm rates can be achieved by utilizing sensor and data fusion techniques in general, utilizing synthetic aperture sonars, combining synthetic aperture sonars and magnetic gradiometers.
3. Navigation accuracy can significantly impact the choice of operational search tactics. Systems with less accuracy will dictate search tactics using shorter tracks in order to achieve acceptable area coverage and/or times. Realistic error estimates and methods to control those errors are operationally critical.
4. Receiving periodic updates from an external source (e.g., Global Positioning System (GPS) or an acoustic long baseline) can minimize navigation errors. However, as internal navigation systems and techniques become more accurate, it is important to remember that update rates must be carefully chosen because it is possible to corrupt good internal navigation data with data from less accurate external updates.
5. Navigation using the GPS system has the potential to significantly reduce errors. However, technical difficulties involved with obtaining a fix may limit their use in operational systems.

Observations pertaining to bottom crawling vehicles:

1. Appropriate use of countermeasures has the potential to significantly reduce crawler effectiveness in the surf zone. Consequently, crawler designs must include counter-countermeasure techniques.
2. Effective countermeasures can be made from readily available supplies.
3. The use of countermeasures can have a significant impact on the choice of search tactics and swarm size.
4. Search pattern effectiveness is dependent of the length of time a crawler must search before changing heading (i.e., "leg length"). An optimum leg length has been determined for tactically relevant lane geometries.
5. Random search tactics with long leg lengths are not dependent on specific area geometry. Search area geometry is important when using short leg lengths during a random search.
6. Specific heading changes do not have a significant impact when searching with long leg lengths.
7. The initial starting position for a lane search will have significant impact on search times in a tactically relevant area. This implies that system delivery issues are critical to mission success.
8. External navigation updates can improve raster (e.g., "lawn mower") search performance. Random search patterns do not benefit from external navigation updates. This implies that there is a tradeoff between navigation system complexity and search tactics.

IMPACT/APPLICATIONS

The overall objective of the Concept Assessment and Development task of the VSW/SZ MCM Reconnaissance Program is to provide a foundation of technologies, operational concepts, and analysis for future systems development. Since systems development is not the primary goal for the current phase of the program, the use of accepted analysis techniques and simulation tools would be critical in the development of effective technologies and the “virtual integration” of systems and system concepts. An efficient, unified, and coordinated analysis environment will provide reliable technical and programmatic input earlier in the development process. This approach will result in lower life cycle costs and higher performance.

TRANSITIONS

Currently, the results of this effort are being used to establish design and operational parameters for VSW/SZ MCM reconnaissance systems in development. This effort will serve as a focal point for new notional concept assessment and will provide a tool to foster transition of those concepts through the entire acquisition cycle. Specific transition opportunities exist for the PMS (EOD) UUV Development Program and the PMS 325 Semi-Autonomous Hydrographic Reconnaissance Vehicle Program.

RELATED PROJECTS

This effort is closely related to the following projects.

- VSW/SZ MCM: Surf Zone Robotics – C. Bernstein
- VSW/SZ Communications – A. Matthews
- Magneto Inductive Baseline Systems for MCM Operations – J. Sojdehei
- Vehicle Group Behavior and Control – C. Duarte
- Future MCM System Alternatives Study – C. McVey
- PMS (EOD) UUV Development Program – R. Simmons
- PMS 325, Semi-Autonomous Hydrographic Reconnaissance Vehicle Program – CDR. Huss